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PHOTOGRAPHIC OBSERVATIONS OF MARS AT NEW MEXICO STATE UNIVERSITY IN 1960-61

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Photographic observations of Mars were made on a regular basis at New Mexico State University during the fall, winter and spring of 1960-61. This apparition included the Martian vernal equinox, which occurred on December 8, just three weeks before opposition. All the observations were made at the 20.12-meter Cassegrain focus of the University's 30-cm reflector.* Although the 10."25/mm plate scale of this system yielded only a 1.5-mm image of Mars at its closest approach, the use of medium and fine grain plates with good contrast permitted the recording of a considerable amount of interesting detail.

Most of the photography was in three color regions: ultraviolet, blue, and red, although a comparatively small number of plates were taken in the yellow and infrared regions. The filters and plate types used are listed in Table I.

The double-slide plateholder used for Cassegrain photography features a monitoring eyepiece arrangement such that the image being photographed is constantly visible to the observer. This is accomplished

*This instrument was made available to New Mexico State University by the United States Army Research Office (Durham).

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by interposition in the light beam of a thin piece of flat Kodak Photographic Glass to reflect a small percentage of the light to the eyepiece. The spectral transmittance of this glass is essentially constant at 90 percent in the range 0.300-0.600μ, and is down only 2 percent at 0.640μ. This arrangement allows exposures to be made during the moments of best seeing, although generally a compromise was made in order not to prolong a given plate more than 30 or 40 minutes. Successive plates could thus be exposed in different colors with a minimum of planet rotation between plates.

TABLE I

PLATE AND FILTER COMBINATIONS

Emulsion	Filter (Schott)	λeff	Number of Plates
II-0, III-0	UG-2	0.375	58
II-0, III-0, IV-0	GG-13	.450	115
III-G, IV-G	OG-5	.590	9
IV-E	OG-2	.640	119
I-N	RG-9	.805	7

The plates were calibrated in the darkroom with an Eastman wedge, using the same filters as were used at the telescope.

A total of 17,680 images were obtained between August 9, 1960, and March 23, 1961. Of these, 64 percent were of fair quality or better, and 7 percent were considered of maximum quality obtainable with 30-cm aperture. Ordinarily, 63 images were recorded on a single plate, but more than twice this number could be exposed without overcrowding.

This was occasionally done during periods of exceptionally good seeing, when exposures could be made at a rapid pace.

In the following account of the results, all directions referred to are directions as they would appear to an observer on the surface of Mars. The same is true for terms such as "afternoon, noon," etc., denoting time of day. However, all dates given are Earth Universal Time dates. The nomenclature of Martian surface features is that of the IAU, except where none is provided for.

Red Photography

Among the more conspicuous features of Mars' appearance in the red was the continued existence of the large dark region near Thoth (λ 250°), which first began to develop in 1952 (Slipher, 1962). This area reached its maximum size in 1954, and has continued in about the same state through the 1960-61 apparition. The nearby Nepenthes canal was also very broad and prominent, as was the Umbra region north of the Syrtis Major (λ 290°).

Margaritifer Sinus (λ 20°) appeared markedly truncated, with a large desert gap separating it from the Oxia Palus to the north. Further northwest, at λ 40°-60°, the broad corridor between Nilokeras I and II appeared to be at least partially filled-in. In the same region, Lunae Palus was large and dark, resembling its appearance when photographed by Slipher (1962) in 1907. At that time Mars was near its autumnal equinox; the 1960 apparition bracketed its vernal equinox.

The Cerberus I canal (λ 210°) was very broad and dark. It appeared to be a long, tapering extension of the Trivium Charontis at its northeast end. Elysium (λ 210°) always appeared very bright in the red; in fact it was invariably the brightest feature on the disk any time it was within 50° of the central meridian. Its contrast with the surrounding desert areas was much greater than in the yellow, although only two yellow plates were obtained of this region.

No yellow clouds were ever noted, although such clouds can easily escape detection in the red unless they encroach over a sizeable portion of a dark surface feature. However, a yellow cloud was observed at Kwasan Observatory on the Isidis Regio (λ 270°) on January 19 (Miyamoto and Nakai, 1961). At that time, this region was not accessible from New Mexico. It was regretted later that more plates were not taken in the green-yellow region. Such plates are not only valuable for seeking out yellow clouds which might otherwise escape unnoticed, but they can also be of value in distinguishing between different cloud types.

Mars never approached nearer than 56 million miles in 1960. Even though such distant apparitions are obviously not favorable for canal photography, a number of them were nevertheless recorded. A list of the canals definitely photographed appears in Table II. A few others were suspected but could not be identified on composite images. In Fig. 1a, a portion of the Gigas Canal may be seen near the equator at the left limb.

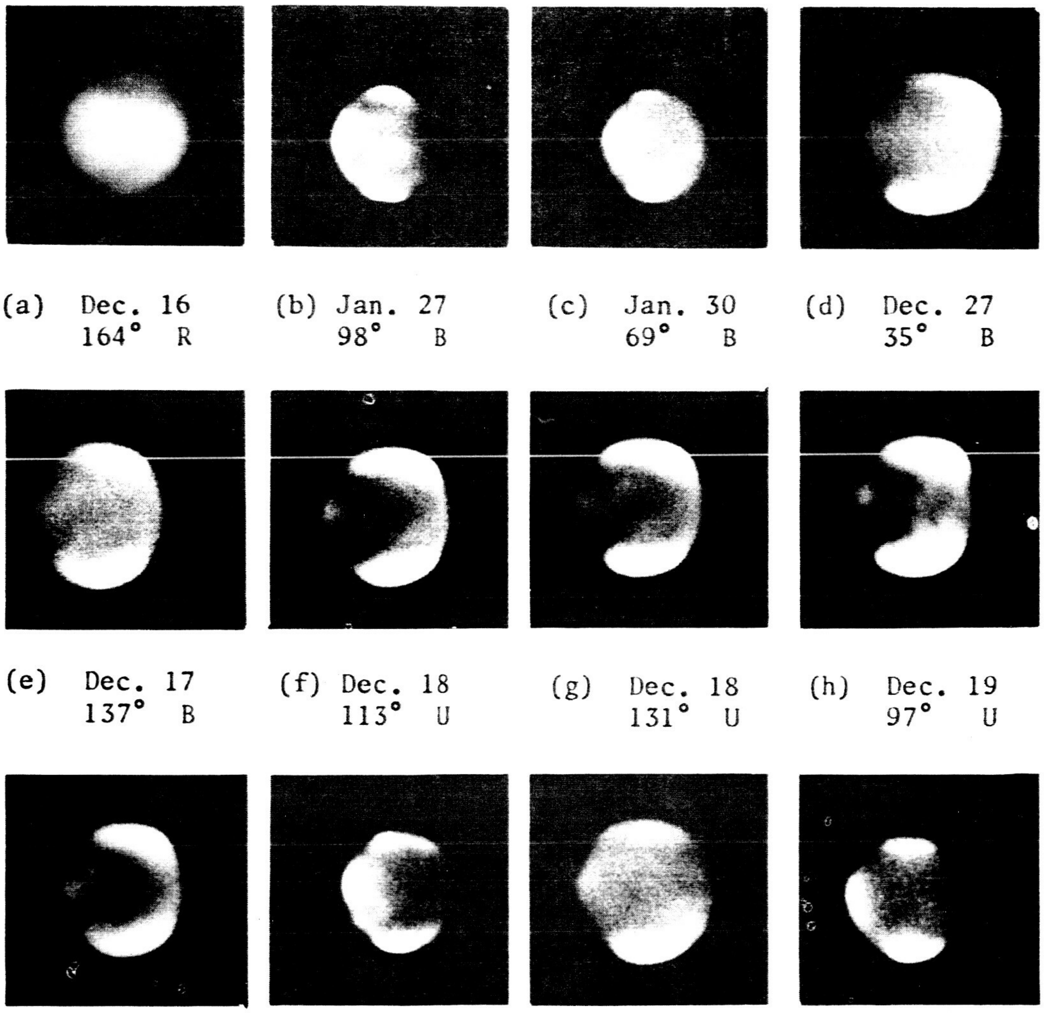
Position Measurements

The 1.5 mm images (at opposition) were much too small for most direct measurements. Except for the polar haze caps, all detail on blue and ultraviolet images was of such low contrast that it became totally lost under the magnification of a measuring microscope. Projection of the images onto a white card was tried, but the same problem was encountered.

TABLE II

CANALS RECORDED ON RED PLATES

Canal	Approximate Longitude	Dates Photographed (U.T.)
Ganges	65°	17, 19, 21 Nov.; 25 Dec.
Indus	20	22 Nov.
Gehon	0	22 Nov.
Sitacus	345	26 Nov.; 27, 29 Dec; 2 Jan.
Astaboras	300	1 Dec.; 13 Jan.
Nilosyrtis	280	13 Jan.
Cerberus I	210	Regularly
Cerberus II	225	6 Dec.; 10 Jan.
Gigas	150	11 Dec.; 20 Dec.; 16, 17 Jan.
Jamuna	50	25, 27 Dec.
Euminides	140	17 Jan.
Orcus	170	20 Dec; 17 Jan.
Titan	170	17 Jan.
Nepenthes	270	Regularly
Cantabras	10	27 Dec.
Hydraotes	40	27 Dec.



(a) Dec. 16 164° R

(b) Jan. 27 98° B

(c) Jan. 30 69° B

(d) Dec. 27 35° B

(e) Dec. 17 137° B

(f) Dec. 18 113° U

(g) Dec. 18 131° U

(h) Dec. 19 97° U

(i) Dec. 20 137° U

(j) Jan. 23 149° U

(k) Jan. 10 241° U

(l) Jan. 16 192° U

FIG. 1. RED (R), BLUE (B), AND ULTRAVIOLET (U) PHOTOGRAPHS OF MARS DURING THE 1960-61 APPARITION.

(Longitudes of the Central Meridian are given for each image)

The method finally adopted was one involving several steps of copying, tracing, and projection. Composite image enlargements were made on Eastman Process plates, utilizing as many original images as could be allowed after consideration of such factors as plate resolution, seeing, planet rotation, and slight variations in image quality (Kirby, 1959). Exposure and processing times were adjusted to yield the highest contrast feasible. Ink tracings of the detail under investigation were then made on transparent plastic, and projected onto a globe from which the co-ordinates of the traced points could be read.

Blue Clouds and Blue Clearing

Blue clouds were so common throughout this apparition that the disk was rarely photographed without at least a vestige of one somewhere. It has long been recognized (Antoniadi, 1930) that "white" clouds are more frequently seen at near-aphelion apparitions of Mars. Although there appears to be a real difference between "white" and "blue" clouds (deVaucouleurs, 1954; Dollfus, 1961) the fact that blue clouds were so common is indicative of a similar origin and/or composition. They occurred most frequently on or near the evening limb, occasionally extending westward in tropical latitudes as far as the central meridian or beyond. They were rarely recorded near the morning limb.

The long cutoff was approximately 0.500μ in the blue, and 0.390μ in UV. Since the clouds were always brighter and somewhat more extensive in UV, they are probably the "blue veils" described by Dollfus (1961) who pointed out that polarization measurements indicated a composition of water droplets about 3μ in diameter.

The principal objective of the blue photography was the detection and study of blue clearings, and the UV plates were intended to serve as confirmation (or a means of rejection) of suspected cases of clearing. Any surface dark markings showing in the blue should be invisible or at least far less apparent in UV. During the course of comparing the plates it was realized that not only was a comparison of the dark markings a good criterion, but also a comparison of bright markings could serve almost as well. As mentioned above, the blue clouds always appeared brighter in ultraviolet. There were some cases where the reverse seemed to be true but more meticulous comparison, utilizing both the dark marking criterion and the method of position measurement described above indicated in every case that these were not clouds at all, but bright desert areas showing through in the blue.

Preliminary results of the search for blue clearing were reported by Smith (1961). A more thorough examination of the plates has resulted in a few modifications of the findings described earlier, notably the addition of nine dates of clearing greater than degree one in January and February. This was due to the use of the "bright marking" criterion (coupled with other techniques such as composite copying) which had not been tried at the time of the earlier paper.

The "bright marking" criterion could obviously be misleading if any white clouds were present, and therefore should never be used by itself as proof of a clearing. However, the same precaution should be adhered to in the judgment of blue clearing by dark markings, except in the more obvious cases. Slipher (1962) and Kuiper (1961) have indicated the occasional occurrence of dark markings in the blue in areas where no such markings exist on the surface.

Such dark "clouds" appear to have been present near $\lambda 80°$ between January 27 and February 1 (Figs. 1b, 1c). Two dark markings corresponding to the positions of Lunae Palus and Tithonius Lacus were prominent on blue plates for five days during this period. In several respects the images had all the appearances of a blue clearing, but the dark markings were far too extensive to be accounted for in this manner. The dark area centered over Lunae Palus was at least ten times larger in area than Lunae Palus itself, and the Tithonius darkening covered about three times the area of the surface feature. Unfortunately, only one ultraviolet plate was obtained during the presence of this phenomenon; it showed the same dark features, but with noticeably lower contrast. If the darkenings merely indicated the absence of bright clouds, the ultraviolet images should have revealed more contrast than the blue.

The time distribution, together with the degree of clearing, is depicted in Fig. 2, using Smith's scheme of representation. The length of the shaded portions represents the degree of clearing on a scale of 0-10, with scale value 1 reserved for doubtful cases. The fact that the September 1 bar is only half the height of the others results from a combination of small image size and comparatively featureless area of the planet (Arcadia-Amazonis) making classification of this date very difficult.

Although no observations were obtained on December 30 (opposition), the most pronounced degree of clearing appears to have occurred for several days on either side of the 30th, and probably includes opposition. There were more cases of post-opposition clearing of degree greater than one: 47 percent of the observed dates, compared to 21 percent before opposition. When all dates of suspected clearing are considered, the preponderance of post-opposition clearing is striking: 84 percent compared to 32 percent before opposition.

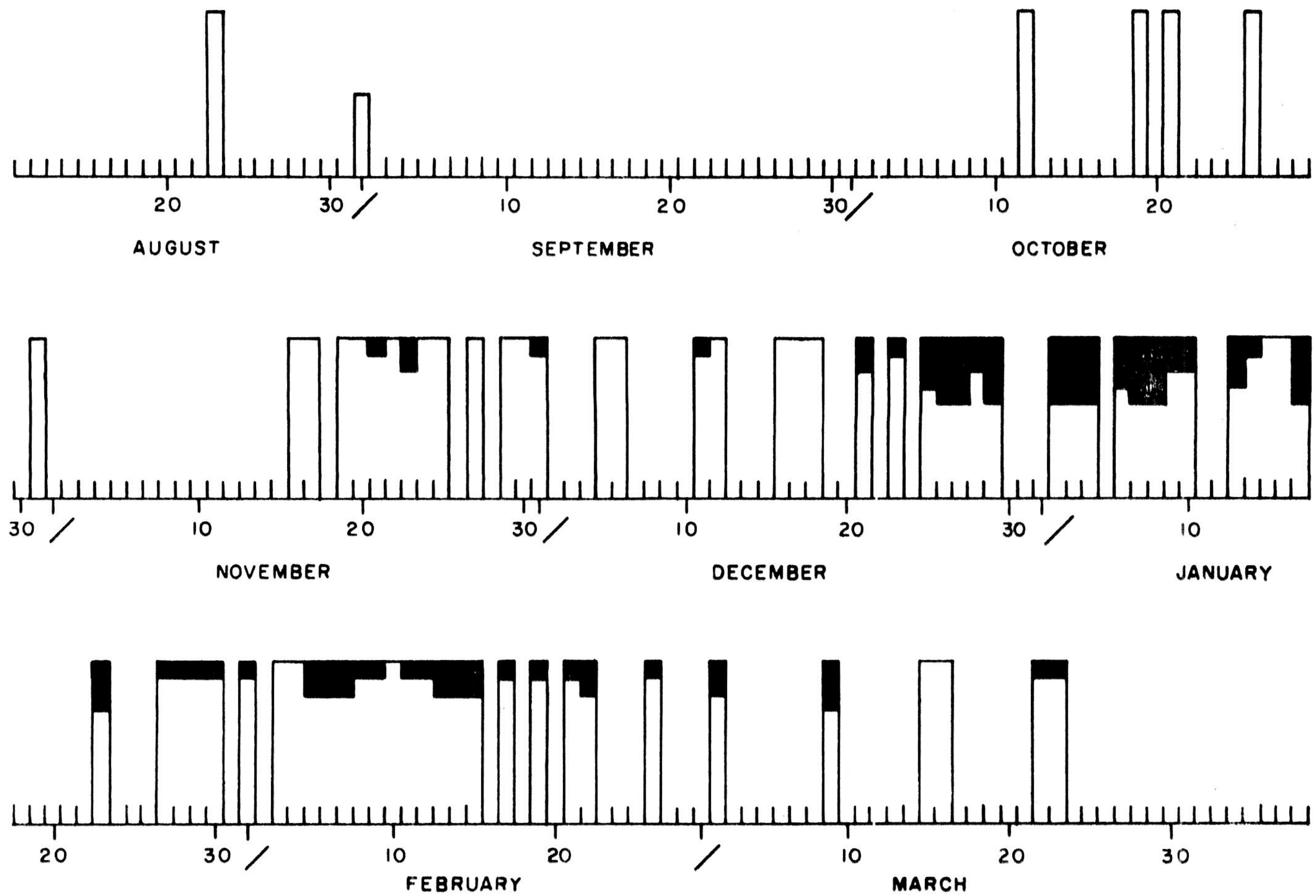


FIG. 2 - BLUE CLEARING IN 1960-61. The vertical bars indicate dates of blue observations. The lengths of the shaded segments denote the degree of clearing.

The relative frequency of blue clearing as a function of areocentric longitude is shown in Fig. 3. An effect of observational selection is suggested by the fact that the most easily identified dark region (Syrtis Major, λ290°) is near the peak of the distribution. However, the peak is actually somewhat to the east of Syrtis Major, in fair agreement with the finding by Slipher (1962) of a peak at 250°, based on far more plates and many apparitions. The maria to the west of Syrtis Major are at least as readily identified as those near 250°, yet the distribution of Fig. 3 declines rather steadily toward the west (from λ250°) all the way to λ150°, at which point there is a comparatively rapid rise.

Sinus Meridiani (λ360°) is invariably one of the darkest regions on the Martian surface, yet it was not discernible in the blue on as many occasions as some other less favorable (observationally) areas.

Variations of clearing with both latitude and longitude were noted on several occasions (Smith, 1961). In Fig. 1d both Sinus Meridiani and Margaritifer Sinus can be seen to the east of the central meridian in the southern hemisphere, but nothing is visible of the prominent Mare Acidalium in the northern hemisphere.

Atmospheric Belts

Bright cloud bands were recorded during the week of January 9-16, when longitudes 180°-360° were photographed. They consisted of two bands, one in each hemisphere parallel to the equator (Figs. 1k and 1). On the other hand, two dark bands can be seen in Fig. 1b, parallel to the equator and apparently emanating from the peculiar dark regions of Lunae Palus and Tithonius Lacus. Similar to the spots, these bands were of lower contrast in the ultraviolet.

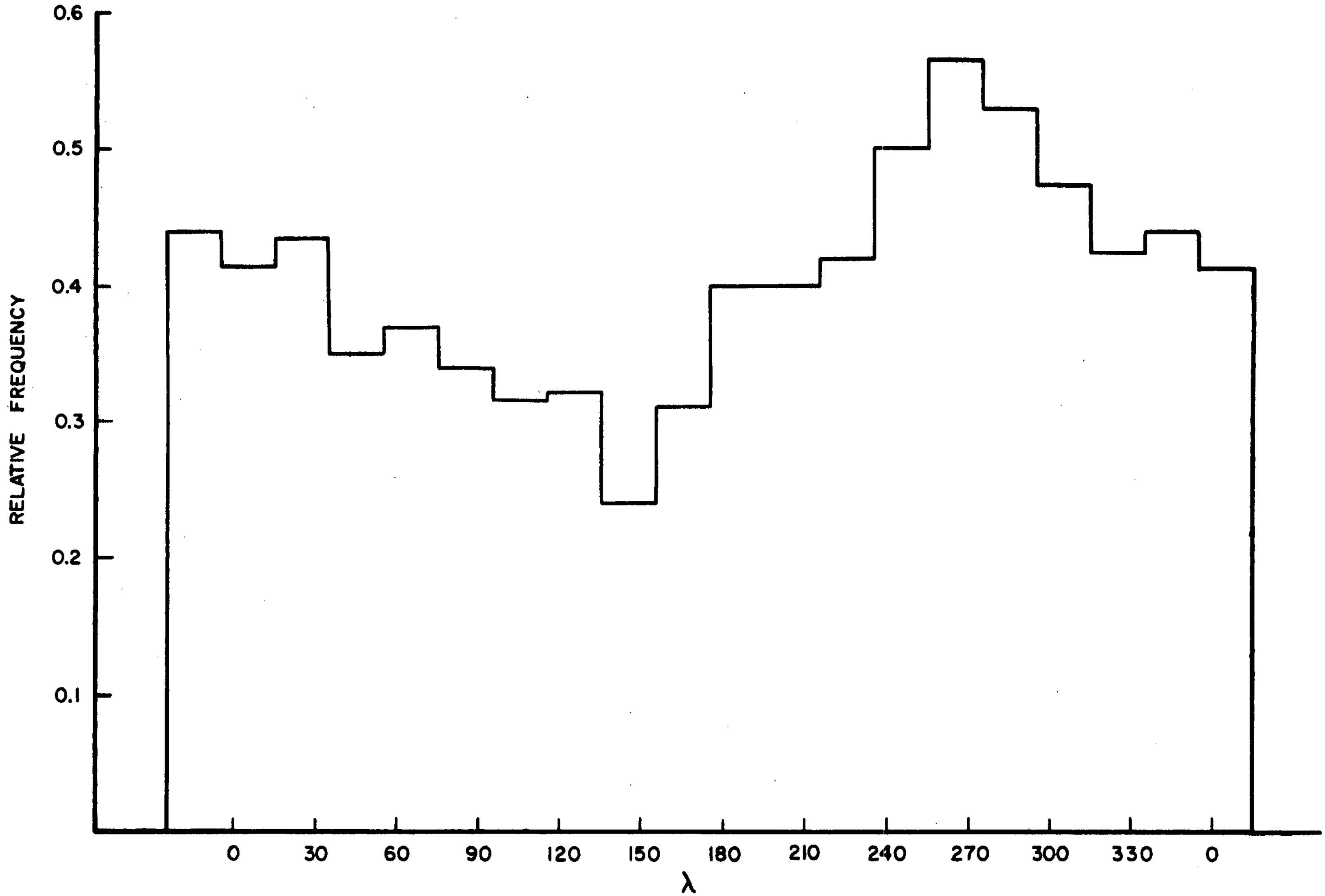


FIG. 3 - LONGITUDE DISTRIBUTION OF BLUE CLEARING, 1960-61 APPARITION

Polar Haze

A bright cap was visible over the north polar region on both blue and ultraviolet images when the first plates were taken August 23. Its southern border appeared to recede for awhile, then advance southward until it reached its lowest latitude on December 19 ($L_s = 5°$, Fig. 4). It was visible throughout the apparition, but by latter March its border appeared to be coincident with that of the cap recorded in the red.

The dramatically sudden appearance of the south polar haze is apparent in Fig. 4. It still was not visible at all as late as December 9 ($L_s = 358°$), yet reached as far north as 31° S. latitude on December 19. After a retreat beyond latitude 60° by mid-February, its border appeared to be advancing northward once again.

Activity in the Tharsis-Amazonis Region

A large bright cloud covered the entire Tharsis region ($\lambda 100°$) during the late afternoon of December 16. It appeared considerably elongated toward the southwest, extending beyond Phoenicis Lacus to $\lambda 120°$. On the 17th a cloud was again present in this position, with much the same appearance. In addition, a bright, tapering streak extended from a limb cloud over Tempe in a southwesterly direction into the southern hemisphere (Fig. 1e). It was slightly to the west of the Gigas-Iunonius canal system and approximately parallel to it. It was brightest and broadest at its northeast end, gradually becoming narrower and fainter as it faded into invisibility near 5° S. latitude, $\lambda 170°$ (Fig. 5).

The first blue plate on December 18 was exposed while Tharsis was still on the morning side of the central meridian.

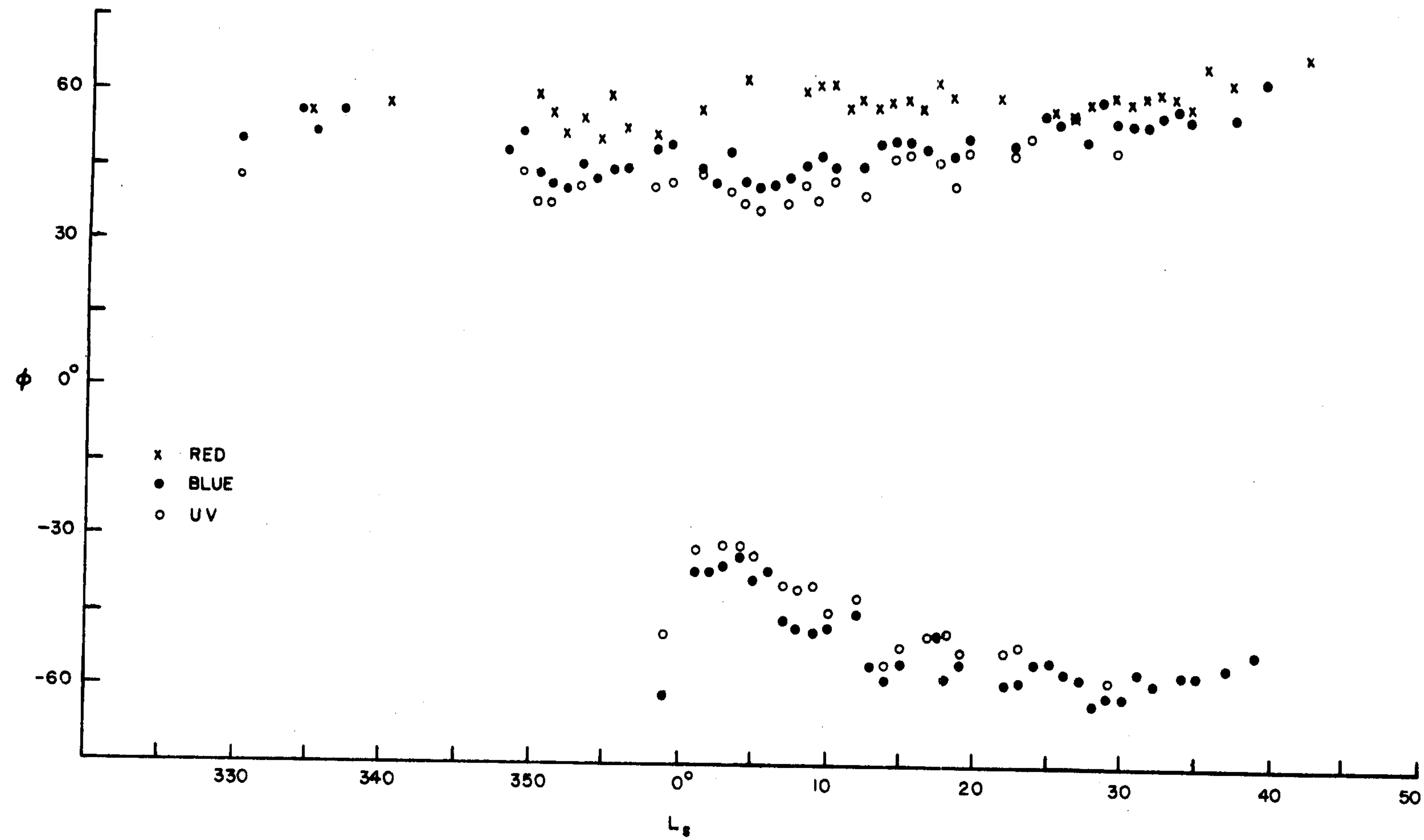


FIG. 4 - LATITUDE LIMITS OF THE MARTIAN POLAR CAPS IN THREE COLORS IN 1960-61. The horizontal axis (L_s) represents areocentric longitude of the Sun.

FIG. 5 - BLUE CLOUD ACTIVITY IN THE THARSIS (T) AND AMAZONIS (A) DESERT REGIONS. Dashed lines indicate approximate limits of the large angular cloud of Fig. 1 g, as well as the persistent linear cloud near the Gigas (G) Canal.

At this time an evening limb cloud was present over Chryse ($\lambda 30°$), with a long extension curving over Ascraeus Lacus ($\lambda 100°$) on the morning side of the central meridian, but nothing was visible over Tharsis or Phoenicis Lacus. A subsequent plate showed this pattern had rotated with the planet, and was still present over the same region.

The first indication of activity near Phoenicis Lacus appeared during the early afternoon in the form of two bright streaks of low contrast, extending from a common point in the southern polar haze boundary toward the northeast and northwest, respectively. The radiant was near the eastern tip of Mare Sirenum, and the eastern streak intersected the Chryse cloud over Tharsis. The western branch extended over Nodus Gordii and reached at least as far as the equator (Fig. 1f). By midafternoon the Tharsis intersection had expanded into a prominent angular cloud (Fig. 1g) similar in both form and position to the "W" cloud recorded in 1954 (Pettit and Richardson, 1955; Slipher, 1962). The Gigas streak was again visible in the same areographic position as the previous day, but appeared considerably broader.

The seeing on December 19 was predominantly poor, but a few ultraviolet images were obtained of sufficient quality to reveal the presence of a considerable amount of linear cloud detail over the entire morning side of the planet. This was the date both polar haze caps extended nearest the equator, and Fig. 1h shows at least three bright streaks actually connecting the two caps.

No further plates were obtained on December 19, but on the 20th over 200° of longitude were covered in a continuous series of ultraviolet plates. Essentially the same sequence of events was observed to occur as that of the 18th, except this time the Mare Sirenum-Tharsis streak was already prominent at midmorning (c.m. 77°). Several hours later (c.m. 138°) the linear streaks had once again expanded and merged to form one huge bright cloud in the late afternoon (Fig. 1i). The Gigas streak was again present in the same position, and could be seen on at least two of the original images to extend all the way to the polar cap boundary in the southern hemisphere. Examination of succeeding plates failed to reveal any change in areographic position of this streak after 33° of rotation of the planet.

Both the Gigas streak and a large limb cloud over Tharsis were photographed again during the following presentation of this region on January 23 (Fig. 1g). Although the southern hemisphere segment of the streak was once again very indistinct, the northern hemisphere portion was brighter and more diffuse than it had been in December. Since the polar haze had receded from its December limits, the northern end of the streak now appeared to curve eastward and terminate in a second limb cloud at about 40° N. latitude.

Some visual observations of Clyde W. Tombaugh are of interest regarding the December cloud activity. Observing independently with a 23-cm reflector, he noted on December 19 and 20 "a suggestion of haze obscuration over the dark markings, especially Mare Erythraeum and Mare Acidalium." In addition, he noted that "the bright markings were nicely enhanced with a green filter."

My thanks are due to Dr. Tombaugh for the use of his map summarizing dark features noted by him in over three decades of visual observations. The work reported here was supported by the National Aeronautics and Space Administration.

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